Nonlinear Photoacoustic Thermoelastic Effect in Stressed Solids

K.L. Muratikov [C, S]
Physical-Technical Institute, Russian Academy of Science, St. Petersburg, Russia

A.L. Glazov
Physical-Technical Institute, Russian Academy of Sciences, St. Petersburg, Russia

D.N. Rose
U.S. Army TACOM, Warren, MI, U.S.A.

J.E. Dumar
Physical-Technical Institute, Russian Academy of Science, St. Petersburg, Russia

A great deal of attention is now paid to the development of methods for residual stress detection. Ultrasonic, Raman spectroscopy, magnetic, X-ray, neutron diffraction methods are usually used for this purpose. Recently holographic interferometry based on the hole-drilling method has also attracted serious attention for solution of this problem. These methods have been already implemented effectively for residual stress detection, while the application of most of them is limited substantially by the physical nature of the used effect. The application of the photoacoustic (PA) thermoelastic effect for diagnostics of mechanical stresses is considered at present with growing interest. The main advantage of the PA thermoelastic method lies in its universal character and in the possibility of application to objects of different nature at microscopic and mesoscopic scales.

The problem of residual stress detection by PA and photothermal (PT) methods has been actively discussed for about twelve years but many important details of this problem were not solved up to now. The main task of this talk is to clear up the situation both by experimental and theoretical investigations. Experimental investigations of the work are based on a new multimode approach proposed by us recently which is able to provide an important opportunity to control elastic, thermal and thermoelastic parameters of materials independently and locally. Different types of PA and PT experiments have been performed. They include PA and PT measurements and imaging of regions near Vickers indentations, PA and PT measurements under annealing, PA and PT imaging of solids under the given external loading. These experiments directly demonstrate the influence of stress on the PA signal and can be used to estimate the sensitivity of the PA method to mechanical stresses in different materials. It is shown that the PA effect in stressed materials is of a new nonlinear type. A model of the PA thermoelastic effect in solids with residual stresses is proposed to explain the results obtained. It is based on the modified Murnaghan model of nonlinear elastic bodies, which takes into account a possible dependence of the elastic and thermoelastic properties of a material on stress. It is demonstrated that the developed theoretical model for the PA piezoelectric effect agrees qualitatively with the available experimental data. The performed theoretical and experimental investigations may result in the development of a scientific base for new NDE methods for residual stress detection. This research was supported by the RFBR and CRDF under award No. PR1-2366-ST-02.